

U.S. Mines Bureau

DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

VAN, H. MANNING, DIRECTOR.

MINE-VENTILATION STOPPINGS

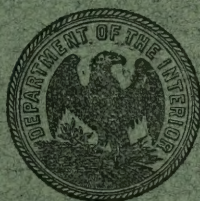
WITH ESPECIAL REFERENCE TO COAL MINES
IN ILLINOIS

BY

R. Y. WILLIAMS

ILLINOIS COAL-MINING INVESTIGATIONS
COOPERATIVE AGREEMENT

[This report was prepared under a cooperative agreement with the
Illinois State Geological Survey and the department of mining
engineering of the University of Illinois]



Bulletin 99

DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

VAN. H. MANNING, DIRECTOR.

MINE-VENTILATION STOPPINGS

WITH ESPECIAL REFERENCE TO COAL MINES
IN ILLINOIS

BY

R. Y. WILLIAMS

ILLINOIS COAL-MINING INVESTIGATIONS COOPERATIVE AGREEMENT

[This report was prepared under a cooperative agreement with the
Illinois State Geological Survey and the department of mining
engineering of the University of Illinois]



WASHINGTON
GOVERNMENT PRINTING OFFICE
1915

The Bureau of Mines, in carrying out one of the provisions of its organic act—to disseminate information concerning investigations made—prints a limited free edition of each of its publications.

When this edition is exhausted copies may be obtained at cost price only through the Superintendent of Documents, Government Printing Office, Washington, D. C.

The Superintendent of Documents *is not an official of the Bureau of Mines*. His is an entirely separate office and he should be addressed:

SUPERINTENDENT OF DOCUMENTS,
Government Printing Office,
Washington, D. C.

The general law under which publications are distributed prohibits the giving of more than one copy of a publication to one person. The cost of this publication is 10 cents.

First edition. September, 1915.

CONTENTS.

	Page.
Purpose of report.....	5
Acknowledgments.....	5
Method of presenting cost data.....	5
Types of stoppings.....	6
Sizes of stoppings.....	7
Number of stoppings required.....	7
Cost of erecting and maintaining stoppings, on a yearly basis.....	8
First cost.....	8
Cost of maintenance of stoppings.....	10
Cost of renewal repairs.....	11
Cost of emergency repairs.....	12
Summary of annual expense for erection and maintenance of stoppings. . .	12
Cost of air leaks through stoppings.....	13
Concrete example of leakage through stoppings.....	14
Data on cost of air leaks through stoppings.....	15
Method of obtaining data.....	15
Computations made.....	16
Summary of costs of erection and maintenance of stoppings.....	16
Descriptions of various types of stoppings.....	17
Gob stoppings.....	17
Board stoppings.....	18
Brick stoppings.....	20
Concrete stoppings.....	21
Line brattices.....	22
Rock-dust-protected stopping.....	22
Collapsible stopping.....	24
Conclusions.....	24
Publications on mine accidents and methods of coal mining.....	26
Index	29

TABLES.

TABLE 1. Number of mine stoppings required for increasing mine develop- ment.....	Page. 8
2. First cost of erecting nine types of stoppings, area of each assumed to be 80 (8 by 10) square feet.....	9
3. Annual expense to amortize first cost of mine-ventilation stoppings.....	10
4. Annual expense to amortize first cost of nine types of stoppings	10
5. Annual maintenance charges for nine types of stoppings.....	11
6. Annual expense for renewal repairs on nine types of stoppings.....	11
7. Annual expense for emergency repairs on different types of stop- pings.....	12
8. Summary of erection and maintenance costs of stoppings, reduced to the annual expense necessary for a period of 15 years.....	13
9. Results of observation of actual efficiencies of mine stoppings.....	14
10. Horsepower required for different efficiencies of stoppings.....	15
11. Cost of air leaks through stoppings of various types.....	16
12. Annual expense for each main-entry stopping having a length of serv- ice of 15 years, in mine with annual production of 200,000 tons....	16
13. Cost of labor for building gob stoppings of different sizes.....	18
14. First costs of concrete-block stoppings.....	21

ILLUSTRATIONS.

PLATE I. <i>A</i> , Gob stopping faced with dry wall of slate and roof coal; <i>B</i> , con- crete block stopping.....	Page. 18
II. <i>A</i> , Gob stopping faced with 12 inches of clay; <i>B</i> , rough-lumber stop- ping coated with wood-fiber cement.....	20
III. <i>A</i> , Rock-dust-protected stopping; <i>B</i> , outer or crosscut end of line brattice, Bureau of Mines experimental mine.....	22
IV. Inner or face end of a line brattice.....	22
FIGURE 1. Properly constructed stopping made of tongued-and-grooved lumber.	19
2. Rough-board stopping, inverted clapboard type.....	20
3. Plan of arched brick stopping.....	21
4. Rock-dust-protected stopping designed by Bureau of Mines.....	23

MINE-VENTILATION STOPPINGS.

By R. Y. WILLIAMS.

PURPOSE OF REPORT.

In this report an attempt is made to discuss the first cost of each of several types of mine-ventilation stoppings, as well as the total annual expense of maintaining a stopping during its required period of service. Such data furnish a basis for comparison of the efficiency of the different types, and are of great importance to an engineer planning the development of a mine. The data given were obtained through an investigation conducted under a cooperative agreement between the Bureau of Mines, the Illinois State Geological Survey, and the department of mining engineering of the University of Illinois. The report itself is published by the Bureau of Mines as a contribution to the literature on safety and efficiency in coal mining.

ACKNOWLEDGMENTS.

The writer wishes to thank the officials of the coal companies who contributed data and to express his appreciation of the assistance of the State mine inspectors and of the engineers of the Bureau of Mines and those working under the direction of the Illinois State Geological Survey and of the department of mining engineering of the University of Illinois. Special thanks are due George S. Rice, chief mining engineer of the bureau, for valuable suggestions on the compilation of data, to John T. Ryan, assistant mining engineer of the bureau, and S. O. Andros, mining engineer, for collecting much information on the efficiency of ventilation stoppings.

METHOD OF PRESENTING COST DATA.

The method adopted for presenting cost data in this report is as follows:

All the installation and maintenance charges, including first cost, maintenance, renewals, and emergency repairs, have been reduced to an annuity basis so as to show the amount of money that must be set aside annually to cover the upkeep and to provide for the amortization of capital at the current rate of interest for a given term of years.

Because the Illinois State mining law specifies the minimum amount of air that must be delivered to each man per minute, and because the sole purpose of each stopping built in crosscuts between the fan and the face is to prevent the air of the ventilating current from passing through the crosscut in which the stopping has been built, the cost of air leaks through stoppings may be found by determining the additional horsepower required by the fan to deliver air from the surface to the stopping through which the air leaks.

As an illustration of this method of presenting data and as an explanation of the terms used, let it be assumed that a number of main-entry stoppings are to be built for a service of 15 years. The items for labor and material in building the stoppings are included in "first cost"; the cost of labor and material required each year to make the stoppings efficient or tight is included under "maintenance charges." In case the material used in building the stoppings has an average life of only five years, the charge for the additional stoppings that must be built to give the 15-year service comes under the head of "renewal repairs." If the stoppings are of such a type as has been found in practice to be subject to destruction by shot firing, explosions, fires, water, etc., "emergency repairs" will be required. If air leaks through the stoppings and increases the volume of ventilation required of the fan, the amount of horsepower necessary to furnish the wasted air will determine the cost of stopping inefficiency, or the "cost of air leaks through stoppings."

TYPES OF STOPPINGS.

The word "stopping" as here used denotes a well or barrier built in a crosscut (termed "cut-through" or "break-through" in Pennsylvania) to prevent air from passing through. The word "brattice" denotes a partition built in a room or entry to conduct the air from the last crosscut to the face.

A great many types of stoppings are in use in the 840 coal mines in Illinois, the types varying from efficient concrete stoppings to inefficient stoppings constructed of powder cans and coal dust. The data in Tables 2 to 12 relate to the following nine types of stoppings:

1. Board stopping, rough lumber.
2. Board stopping, tongue and groove.
3. Board stopping, planed on two sides and painted.
4. Brick stopping, 4-inch wall.
5. Brick stopping, 8-inch wall.
6. Concrete monolith, 8-inch wall.
7. Concrete blocks, 8-inch wall.
8. Slate or gob, dry wall.
9. Slate or gob, faced with cement.

The list indicates the scope of the investigation herein reported. The main purpose is to suggest a way in which a superintendent or mine manager may solve mine-stopping problems by substituting particular values for those given in the tables.

SIZES OF STOPPINGS.

The dimensions of stoppings vary as follows:

Height.....	4 feet 6 inches to 9 feet.
Width	8 feet to 25 feet.
Thickness.....	1 inch to 20 feet.
Average surface area	79 square feet.

The variations in height are due to differences both in the thickness of the coal and in the physical properties of the beds. In some of the beds a strong top coal is left as the roof and in others a "draw slate" above the coal is removed in mining. Otherwise the stopping height is usually the same as the thickness of the coal bed.

The width of stoppings varies between the wide limits mentioned above because of the attempt at some mines to reduce the yardage in crosscuts by driving them full width. The objections to that method are that wide areas of roof are left unsupported and that wide stoppings increase the air leakage. Except in gob stoppings, the width of stopping is made 12 to 36 inches wider than the crosscut in order that the stopping may be "set in" a groove or channel which is cut in the rib to make a tight joint.

The thickness of the stopping varies with the material of which it is constructed, and, in the case of gob stoppings, with the amount of waste rock made in entry driving.

As crosscuts in Illinois mines should have an area of not less than 36 square feet when used for the passage of air, the smallest stopping will have a surface area, including the groove, of about 50 square feet. The higher limit should not be over 100 square feet. In the following tables, all data relating to stoppings are reduced to a common basis, that for a stopping having an area of 80 square feet, which is approximately the average size of Illinois stoppings.

NUMBER OF STOPPINGS REQUIRED.

In the usual room-and-pillar mine in Illinois, where the coal beds average $5\frac{1}{2}$ feet in thickness and crosscuts are driven on 70-foot centers, the building of two entry stoppings for every acre of coal bed developed is required. In that State in 1913 there were 114 individual mines with an output of more than 200,000 tons of coal. This output required at each mine the development of about 50 acres and the construction of 100 new entry stoppings, of which 25 per cent were on main entries and 75 per cent on cross entries.

Table 1 shows the averages of many observations made to determine the total number of stoppings required for various acreages developed, and the total number of main and cross-entry stoppings in actual use at different periods in the development of a mine.

TABLE 1.—*Number of mine stoppings required for increasing mine development.*

Total mine development (acres).	Number of stoppings.			Number of stoppings in actual use.		
	Main entry.	Cross entry.	Total.	Main entry.	Cross entry.	Total.
100.....	50	150	200	50	150	200
200.....	100	300	400	100	300	400
300.....	150	450	600	150	400	550
400.....	200	600	800	200	400	600
500.....	250	750	1,000	250	400	650
600.....	300	900	1,200	300	400	700
700.....	350	1,050	1,400	350	400	750
800.....	400	1,200	1,600	400	400	800
900.....	450	1,350	1,800	450	400	850
1,000.....	500	1,500	2,000	500	400	900
1,500.....	750	2,250	3,000	600	400	1,000
2,000.....	1,000	3,000	4,000	800	400	1,200

COST OF ERECTING AND MAINTAINING STOPPINGS, ON A YEARLY BASIS.

FIRST COST.

Where a coal bed must be developed by expensive shafts it is considered necessary to have at least 2,000 acres tributary to each hoisting shaft. This acreage will require 4,000 stoppings, having a first cost of \$20,000 to \$60,000, a fact that shows how heavy an item in the development of a coal mine the cost of stoppings may be.

In the following table is given the first cost of nine types of stoppings. The items for materials and labor represent the average figures determined from a large amount of information submitted by coal operators. For each stopping, except the gob type, the labor item covering the building of the stopping includes the cost of cutting a latch or groove in the ribs for "setting in" the stopping.

TABLE 2.—First cost of erecting nine types of stoppings, area of each assumed to be 80 (8 by 10) square feet.

Kind of stopping.	Cost of materials.				Cost of labor.				Total first cost.
	Item.	Quantity.	Rate.	Amount.	Item.	Hours.	Rate.	Amount.	
Board, rough lumber.	Boards....	0.10 board feet.	\$25.00	\$2.50	Delivery..	2	\$0.32	\$0.64	\$7.34
	Nails.....	1 pound.....	.04	.04	Building..	10	.32	3.20	
	Posts.....	4.....	.08	.32	Calking... 2	.32		.64	
	Total.....			2.86	Total.....			4.48	
Board, tongue and groove.	Boards....	0.10 board feet.	35.00	3.50	Delivery..	2	.32	.64	8.38
	Nails.....	2 pounds.....	.04	.08	Building..	10	.32	3.20	
	Posts.....	4.....	.08	.32	Calking... 2	.32		.64	
	Total.....			3.90	Total.....			4.48	
Board, s2s, painted.	Boards....	0.10 board feet.	35.00	3.50	Delivery..	2	.32	.64	9.27
	Nails.....	2 pounds.....	.04	.08	Building..	10	.32	3.20	
	Posts.....	4.....	.08	.32	Calking... 2	.32		.64	
	Paint.....	1 can.....	.25	.25	Painting.. 2	.32		.64	
	Total.....			4.15	Total.....			5.12	
Brick, 4-inch wall.	Brick.....	0.7 thousand..	7.00	4.90	Delivery..	2	.32	.64	10.27
	Cement....	1 barrel.....	2.00	2.00	Building..	8	.32	2.56	
	Sand.....	0.4 yard.....	.42	.17					
	Total.....			7.07	Total.....			3.20	
Brick, 8-inch wall.	Brick.....	1.2 thousand..	7.00	8.40	Delivery..	2	.32	.64	17.43
	Cement....	1.8 barrels.....	2.00	3.60	Building..	14	.32	4.48	
	Sand.....	$\frac{3}{4}$ yard.....	.42	.31					
	Total.....			12.31	Total.....			5.12	
Concrete monolith, 8-inch wall.	Cement....	1.2 barrels.....	2.00	2.40	Delivery..	2	.32	.64	11.57
	Sand.....	0.35 cubic yard.	.42	.15	Building..	20	.32	6.40	
	Form, nails, tools, etc.			1.50					
	Stone.....	0.95 cubic yard	.50	.48					
	Total.....			4.53	Total.....			7.04	
Concrete blocks, 8 by 8 by 16, 8-inch wall.	Blocks....	90.....	.05	4.50	Delivery..	2	.32	.64	10.32
	Cement....	2 sacks.....	.30	.60	Building..	14	.32	4.48	
	Sand.....		.10	.10					
	Total.....			5.20	Total.....			5.12	
Slate or gob, dry wall.					Building..	22 $\frac{1}{2}$	.32	7.20	7.20
Slate or gob, cement-faced, 1-inch.	Cement....	0.7 barrel.....	2.00	1.40	Building..	22 $\frac{1}{2}$	.32	7.20	10.05
	Sand.....	0.4 yard.....	.42	.17	Facing.... 4	.32		1.28	
	Total.....			1.57	Total.....			8.48	

In order to show the annual expense necessary to bring about the amortization of the first cost at the end of the period of years during which service is required, the following formula may be used:

$$x = \frac{C}{(1+r)^n - 1}$$

Where C=First cost in dollars for construction.

n=Number of years of service required of stopping.

r=Current rate of interest.

x=Number of dollars that must be put away at r interest which will yield C dollars in n years.

and xr =Annual expense necessary to yield C dollars in n years.

With the aid of the formula, Table 3 following has been prepared to show the annual expense necessary to amortize first costs varying from \$5 to \$15 during periods of service of 3 to 20 years.

TABLE 3.—*Annual expense to amortize first cost of mine-ventilation stoppings.^a*

First cost.	Length of service, years.									
	3	4	5	6	7	8	9	10	15	20
\$5.....	\$1.58	\$1.14	\$0.88	\$0.71	\$0.59	\$0.50	\$0.43	\$0.38	\$0.21	\$0.14
\$6.....	1.89	1.37	1.06	.86	.71	.61	.52	.46	.26	.16
\$7.....	2.21	1.60	1.24	1.00	.83	.71	.61	.53	.30	.19
\$8.....	2.53	1.84	1.41	1.14	.95	.81	.70	.61	.34	.22
\$9.....	2.84	2.07	1.59	1.29	1.07	.91	.78	.69	.39	.24
\$10.....	3.16	2.30	1.76	1.43	1.19	1.01	.87	.76	.43	.27
\$11.....	3.47	2.53	1.94	1.57	1.31	1.11	.96	.84	.47	.30
\$12.....	3.79	2.74	2.12	1.71	1.43	1.21	1.04	.92	.51	.33
\$13.....	4.12	2.97	2.30	1.86	1.54	1.31	1.13	.99	.56	.35
\$14.....	4.42	3.20	2.47	2.00	1.66	1.41	1.22	1.07	.60	.38
\$15.....	4.74	3.43	2.65	2.14	1.78	1.51	1.30	1.15	.64	.41

^a Figures calculated from formula $Cr = \frac{Cr}{(1+r)^n - 1}$.

The annual sum to be charged to amortization of the first cost of the nine types of mine stoppings represented in Table 2 is given in Table 4 following:

TABLE 4.—*Annual expense to amortize first cost of nine types of stoppings.*

Kind of stopping.	Total first cost.	Annual sum to amortize first cost for period of 15 years.
Board, rough lumber.....	\$7.34	\$0.31
Board, tongue and groove.....	8.38	.36
Board, planed on two sides and painted.....	9.27	.40
Brick, 4-inch wall.....	10.27	.44
Brick, 8-inch wall.....	17.43	.74
Concrete monolith, 8-inch wall.....	11.57	.49
Concrete blocks, 8-inch wall.....	10.32	.44
Slate or gob, in dry wall.....	7.20	.31
Slate or gob, faced 1 inch with cement.....	10.05	.43

COST OF MAINTENANCE OF STOPPINGS.

The data presented in Table 1 indicate that most of the main-entry stoppings and many of those on the cross entries must be kept in good repair in order that the ventilation for any given development may be maintained in accordance with the State mining law. In carelessly constructed stoppings of lumber or gob material, it was frequently found that the maintenance cost amounted to \$1 per stopping per year, a figure that is larger than the annual expense due to the first cost of a substantial stopping with amortization in a 15-year period. The annual maintenance charges, therefore, assume importance in mine economy.

The cost of maintenance is usually given as a yearly charge, and in that form may be combined directly with other cost items to obtain the total annual expense of stoppings. Maintenance charges on nine types of stoppings are given in Table 5.

TABLE 5.—*Annual maintenance charges for nine types of stoppings.*

[Stoppings 8 by 10=80 square feet; labor at 32 cents per hour.]

Kind of stopping.	Nature of repairs.	Frequency of repairs.	Cost of repairs per annum.		
			Material.	Labor.	Total.
Board, rough lumber.....	Lumber replacement..	Once per annum.....	\$0.50	\$0.32	\$0.82
Board, tongue and groove.....	Calking.....	do.....		.32	.32
Board, planed on two sides and painted.....	Calking and painting..	Once every 2 years.....	.20	.32	.52
Brick, 4 inches thick.....	Cementing on ribs.....	Once every 3 years.....	.10	.16	.26
Brick, 8 inches thick.....	do.....	Once every 4 years.....	.08	.11	.19
Concrete monolith, 8 inches thick.....	do.....	do.....	.08	.11	.19
Concrete blocks, blocks 8 by 10 by 20 inches.....	do.....	do.....	.08	.11	.19
Slate or gob in dry wall....	Retamping at top.....	Once every 6 months.....		1.28	1.28
Slate or gob dry wall, faced with cement.....	Refacing.....	Once per annum.....	.25	.64	.89

COST OF RENEWAL REPAIRS.

When the length of service required of a stopping is longer than the life of the materials used in construction, renewals will be necessary. The average main-entry stopping will have to give 15 years of service, and the cross-entry stopping 3 years. The choice of the type of stopping, therefore, should follow a comparison of the probable length of service of the stopping with the life of the materials to be used in its construction.

Table 6 gives data, obtained from mining companies in Illinois, on the life of the materials used in building stopping, and on the annual renewal expense necessary for a period of 15 years.

TABLE 6.—*Annual expense for renewal repairs on nine types of stoppings.*

[This table is of value in the consideration of main-entry stoppings.]

Kind of stopping.	Average life.	Cost of each renewal.	Annual renewal expense for period of 15 years.
	Years.		
Board, rough lumber.....	3	\$7.34	\$1.24
Board, tongue and groove.....	4	8.38	1.08
Board, s2s, painted.....	5	9.27	.80
Brick, 4 inches thick.....	8	10.27	.44
Brick, 8 inches thick.....	a 15		
Concrete monolith, 8 inches thick.....	a 15		
Concrete blocks, blocks 8 by 10 by 20 inches.....	a 15		
Slate or gob in dry wall.....	a 15		
Slate or gob dry wall, faced with cement.....	a 15		

a Or more.

COST OF EMERGENCY REPAIRS.

The foregoing discussion of renewals deals with the depreciation of stoppings through normal mining conditions. There are, however, extraordinary agencies that destroy stoppings, some of these agencies partly or wholly wrecking certain types of stoppings and yet in no way injuring other types. Such agencies are: Fires, windy shots, blown-out shots, explosions, local roof falls, general mine squeezes, and water.

In order to obtain the annual expense for emergency repairs on the different kinds of mine stoppings, information was obtained from coal operators regarding the number of stoppings and the cost of repairs each year because of these extraordinary agencies. The quotient obtained by dividing the total cost by the number of stoppings in use at the particular mine was charged to each stopping as the annual cost of emergency repairs. For example, at one mine the records showed that 18 stoppings were destroyed by windy or blown-out shots; the cost of each repair averaged \$6.67; the total cost was \$120.06; and, as 1,000 stoppings were in use, the expense to be distributed over each stopping was 12 cents per annum.

A compilation of the information obtained on the annual expense required for emergency repairs is given in Table 7 following.

TABLE 7.—*Annual expense for emergency repairs on different types of stoppings.*

Kind of stopping.	Number of stoppings destroyed per annum, per 1,000 in use, by—							Cost of each repair.	Annual expense per stopping for emergency repairs.
	Fires.	Windy shots.	Blown-out shots.	Explosions.	Local falls.	Squeezes.	Total.		
Board, rough lumber.....	2	5	5	2	2	2	18	\$7.34	\$0.13
Board, tongue and groove.	2	5	5	2	2	2	18	8.38	.15
Board, planed on two sides and painted.....	2	5	5	2	2	2	18	9.27	.17
Brick, 4 inches thick.....	0	2	2	2	0	1	7	10.27	.07
Brick, 8 inches thick.....	0	0	0	2	0	0	2	17.43	.03
Concrete monolith, 8 inches thick.....	0	0	0	2	0	0	2	11.57	.02
Concrete blocks, blocks 8 by 10 by 20 inches.....	0	0	0	2	0	0	2	10.32	.02
Slate or gob, in dry wall...	0	0	0	2	0	0	2	7.20	.01
Slate or gob dry wall, cement faced.....	0	0	0	2	0	0	2	10.05	.02

SUMMARY OF ANNUAL EXPENSE FOR ERECTION AND MAINTENANCE OF STOPPINGS.

A summary of the data in Tables 4 to 7 gives the total annual expense for erecting and maintaining each of nine types of stoppings during a period of 15 years.

TABLE 8.—*Summary of erection and maintenance costs of stoppings, reduced to the annual expense necessary for a period of 15 years.*

Kind of stopping.	Annual expense for 15 years.				
	First cost.	Maintenance.	Renewals.	Emergency repairs.	Total.
Board, rough lumber.....	\$0.31	\$0.82	\$1.24	\$0.13	\$2.50
Board, tongue and groove.....	.36	.32	1.02	.15	1.85
Board, planed on two sides and painted.....	.40	.52	.80	.17	1.89
Brick, 4 inches thick.....	.44	.26	.44	.07	1.21
Brick, 8 inches thick.....	.74	.19	.....	.03	.96
Concrete monolith, 8 inches thick.....	.49	.19	.....	.02	.70
Concrete blocks, blocks 8 by 10 by 16 inches.....	.44	.19	.....	.02	.65
Slate or gob, in dry wall.....	.31	1.28	.....	.01	1.60
Slate or gob dry wall, faced with cement.....	.43	.89	.....	.02	1.34

COST OF AIR LEAKS THROUGH STOPPINGS.

The sole purpose of a stopping is to prevent the air of the ventilating current from passing through the crosscut in which the stopping stands. The Illinois mining law specifies the minimum amount of air that must be delivered to each man per minute. With a given number of men, therefore, a definite quantity of air per minute should pass through the last crosscut of each split. If the stoppings are absolutely tight, the horsepower required by the fan to furnish this air may be obtained by the formula:

$$\text{Horsepower} = \frac{k s v^3}{33,000}$$

Where $k=0.000,000,021,7^a$

s =rubbing surface in square feet

v =velocity in feet per minute

If the stoppings are not tight, air will leak through each crosscut. The amount of this leakage will depend on the area of the hole or crack in the stopping and on the difference between the air pressures on the two sides. It is obvious that if air is lost before it reaches the working faces, additional air must be delivered by the fan in order to have the desired volume reach the last crosscut. Inasmuch as the horsepower required to move the air varies as the cube of the velocity, a serious leakage will require a great increase of horsepower to move the larger volume of air at the higher velocity. At Illinois coal mines a horsepower costs about \$40 per year, including all engine and transmission losses. Therefore, if the quantity of air lost be known, it is possible to figure accurately the cost of the leaks through the mine stoppings. This cost of stopping inefficiency should be charged against the cost of stoppings quite as much as first cost, maintenance charges, etc.

^a The value of k is empiric and is based on investigation by J. J. Atkinson. Other investigations have given different values. The friction constant should vary for the different points of air passage in the mine; but as the result would complicate without seriously affecting the present problem, the generally used value of k as given is assumed to operate continuously.

Table 9 gives results of observation made in Illinois mines to determine the general efficiencies of mine stoppings. This table shows for each mine the quantity of air delivered by the fan and the percentage of the total air reaching the last crosscut. The leakage is surprisingly large.

TABLE 9.—*Results of observation of actual efficiencies of mine stoppings.*

Mine No	County.	Fan.	Size of fan.	Quantity of air at fan.	Quantity of air at last crosscut.	Proportion of air reaching crosscut.
			<i>Feet.</i>	<i>Cubic feet.</i>	<i>Cubic feet.</i>	<i>Per cent.</i>
1	Franklin.....	Robinson.....	18 by 8	119,533	18,232	15.3
2	do.....	Paddlewheel.....		120,410	16,737	13.9
3	do.....	Stevens.....	14	65,300	6,160	9.4
4	do.....	Capell.....	20 by 7½	120,000	40,000	33.3
5	do.....	Paddlewheel.....	21 by 6	64,700	15,600	24.1
6	Williamson.....	do.....		59,827	7,035	11.7
7	do.....	Blakslee.....	20 by 6	96,000	22,140	23.0
8	do.....	Paddlewheel.....	21 by 6	50,400	3,840	7.6
9	do.....	Serocco.....	12	38,160	12,300	32.2
10	do.....	Paddlewheel.....	12	35,290	5,125	14.5
11	Macoupin.....	do.....		77,364	9,600	12.4
12	do.....	Miller.....	18 by 6	160,276	37,672	23.5
13	Christian.....	Paddlewheel.....	14 by 4	28,130	2,380	8.5
14	St. Clair.....	do.....	16 by 4	90,000	12,000	13.3
15	do.....	do.....	16 by 4	62,240	10,950	17.6
16	Sangamon.....	do.....	16 by 5	69,400	23,250	33.5

CONCRETE EXAMPLE OF LEAKAGE THROUGH STOPPINGS.

To show the effect of leakage of air through stoppings on the required horsepower at the fan to deliver a given volume of air at the last crosscut let the conditions outlined below be assumed. The conditions are chosen to represent, as nearly as possible, actual mining conditions in Illinois.

Area developed, acres.....	600
Size of air compartment of shaft, feet.....	6 by 10
Depth of shaft, feet.....	250
First split of air at foot of shaft; secondary splits 400 feet from shaft.	
Total number of splits.....	4
Height of entries, feet.....	6
Width of entries, feet.....	10
Number of men on each split.....	80
Total number of men in mine.....	320
Volume of air required at last crosscut on each split, cubic feet per minute.....	9,000
Total air in mine at last crosscut, cubic feet per minute.....	36,000
Number of main-entry stoppings on each split.....	75
Number of main-entry stoppings in mine.....	300
Number of entry stoppings in use on cross entries in each split.....	100
Number of cross-entry stoppings in use.....	400

In figuring the total horsepower on the air three factors must be considered, as follows: (a) All the air delivered by the fan passes through both the air shaft and the hoisting shaft; (b) one-half the total air travels each way from the foot of the shaft to the secondary

splittings; (c) one-quarter of the total air passes from the secondary splittings to each of the four splits. In the present problem it is assumed that no air is lost while the ventilation current is passing from the fan to the secondary splitting.

Table 10 shows the horsepower required on the air under varying ventilation efficiencies when the other conditions remained as assumed above. The term "ventilation efficiency" in this table represents the ratio between the volume of air reaching the last crosscuts and the volume delivered by the fan. In this particular problem it represents the efficiency of 4 lines of 75 main-entry stoppings in preventing the leakage of air through the crosscuts in which these stoppings are built.

TABLE 10.—Horsepower required for different efficiencies of stoppings.^a

Section of mine. ^b	Percentage of air delivered by fan that reaches last crosscut.					
	100 per cent.	50 percent.	40 percent.	30 percent.	20 percent.	10 per cent.
Shaft ($a=60$; $o=32$; $l=500$):						
Quantity of air, cubic feet per minute.....	36,000	72,000	90,000	120,000	180,000	360,000
Velocity of air, feet per minute.....	600	1,200	1,500	2,000	3,000	6,000
Horsepower required.....	2.27	18.18	35.51	84.17	284.07	2,272.00
Shaft bottom to secondary splits ($a=60$; $o=32$; $l=400$):						
Quantity of air, cubic feet per minute.....	18,000	36,000	45,000	60,000	90,000	180,000
Velocity of air, feet per minute.....	300	600	750	1,000	1,500	3,000
Horsepower required.....	0.45	3.64	7.10	16.84	56.82	454.52
Four separate splits ($a=60$; $o=32$; $l=24,500$):						
Quantity of air, cubic feet per minute.....	9,000	18,000	22,500	30,000	45,000	90,000
Velocity of air, feet per minute.....	150	300	375	500	750	1,500
Horsepower required.....	6.96	27.84	43.50	77.33	174.00	695.99
Total horsepower required.....	9.68	49.66	86.11	178.34	514.89	3,423.11
Cost at \$40 per horsepower.....	\$387.20	\$1,986.40	\$3,444.40	\$7,133.60	\$20,595.60	\$136,924.40

^a Efficiency is considered 100 per cent when all the air from fan travels throughout the mine. When efficiency is less than 100 per cent all the air is assumed to travel through a distance equal to l multiplied by the figure for the percentage of air reaching the last crosscut.

^b a =area; o =rubbing surface; l =length of entry.

DATA ON COST OF AIR LEAKS THROUGH STOPPINGS.

METHOD OF OBTAINING DATA.

In obtaining the data and in making the computations for determining the cost of horsepower lost by the leakage of air through mine stoppings the following method was used:

In the entry or part of an entry chosen the stoppings were all of the same type of construction and the travel of the air was confined to the entry. The stoppings were examined, and their number, type, cost, condition, etc., were recorded. The volumes of air passing the starting and the finishing points on the entry were carefully measured.

COMPUTATIONS MADE.

The difference between the volume at the starting point and that at the finishing point was taken to represent air lost through the stoppings. As all the stoppings were of the same type in each test and as their number was small, it was assumed that the air leaked equally through each stopping.

From a series of tests an average figure was obtained to represent the volume of air that under normal conditions would pass through each of the different types of stoppings. The volume varied widely for each type because of differences in air pressures and in tightness. The average values were used in figuring the stopping costs in the example cited above. It was assumed that one-half of all air "lost" in traveling through the mine was short-circuited through doors.

Table 11 shows the average volume of air lost through each stopping, the resulting total mine efficiency, and the annual cost of air leakage for each of nine types of stoppings.

TABLE 11.—*Cost of air leaks through stoppings of various types.*

Kind of stopping.	Ventilation efficiency of entire mine.	Air leakage per stopping per minute.	Annual cost of air leakage per stopping.
	<i>Per cent.</i>	<i>Cubic feet.</i>	
Board, rough lumber.....	15	340	\$74.49
Board, tongue and groove.....	25	180	19.06
Board, planed on two sides and painted.....	35	171	8.04
Brick, 4 inches thick.....	70	26	1.48
Brick, 8 inches thick.....	85	10	.95
Concrete monolith, 8 inches thick.....	90	6	.83
Concrete blocks, blocks 8 by 10 by 20 inches.....	90	6	.83
Slate or gob dry wall.....	20	240	34.33
Slate or gob dry wall, faced with cement.....	35	171	8.04

SUMMARY OF COSTS OF ERECTION AND MAINTENANCE OF STOPPINGS.

Table 12 gives the total yearly expense for each of the nine types of stoppings. It should be remembered that the figures apply to mines in which 100 cubic feet of air per man per minute is delivered to the last crosscut on each main split, and where approximately 200,000 tons of coal is produced per annum. In smaller mines the cost of air leaks might be less, owing to lower ventilating pressures.

TABLE 12.—*Annual expense for each main-entry stopping having a length of service of 15 years, in mine with annual production of 200,000 tons.*

Kind of stopping.	First cost.	Cost of maintenance.	Cost of renewal repairs.	Cost of emergency repairs.	Cost of air leaks.	Total.
Board, rough lumber.....	\$0.31	\$0.82	\$1.24	\$0.13	\$74.49	\$76.99
Board, tongue and groove (well calked).....	.36	.32	1.02	.14	19.06	20.91
Board, s2s, painted (well calked).....	.40	.52	.80	.15	8.04	9.93
Brick, 4 inches thick.....	.44	.26	.44	.07	1.48	2.69
Brick, 8 inches thick.....	.74	.19	.....	.03	.95	1.91
Concrete monolith, 8 inches thick.....	.49	.19	.....	.02	.83	1.53
Concrete blocks, 8-inch wall.....	.44	.19	.....	.02	.83	1.48
Slate or gob, in dry wall.....	.31	1.28	.....	.01	34.33	35.93
Slate or gob, dry wall, faced with cement...	.43	.89	.....	.02	8.04	9.38

DESCRIPTIONS OF VARIOUS TYPES OF STOPPINGS.

GOB STOPPINGS.

Most of the stoppings in Illinois are built of gob material. The dimensions vary as follows: Height, $4\frac{1}{2}$ to $7\frac{1}{2}$ feet; length, 6 to 25 feet; thickness, 6 to 20 feet. Generally the gob material is merely thrown into the crosscut; frequently one or both sides are built up with a dry wall of "slate;" sometimes the wall is laid in cement or is luted with clay, and occasionally a concrete exterior is made by building a form about 12 inches in front of the wall and tamping concrete in the space thus obtained.

The following general objections apply to the use of gob material for stoppings:

1. The labor item in the first cost is high (see Table 13). Except where the hoisting equipment is overcrowded in handling the coal output, the gob material in excess of the storage room underground could be more cheaply handled by loading it into cars and dumping it into some form of conveyor on the surface by means of a deflecting bottom in the weigh pan.

2. The maintenance is usually expensive, costing from 60 to 90 cents per stopping per year.

3. In time of danger, the gob stopping is not tight enough to seal off fires, leaves much débris to be cleaned up after an explosion, is not packed tight enough to assist in preventing the spread of a mine squeeze, and usually contains much dry coal dust, which aids in the propagation of an explosion.

4. A large volume of air leaks through a gob stopping.

Plate I, *A*, shows a gob stopping 6 feet thick and faced on each side with a dry wall of "slate" and roof coal. Some stoppings of this type showed a leakage of air amounting to 1,300 cubic feet per minute per stopping.

In one mine, because of a serious leakage of air, each of the gob stoppings was coated with 12 inches of clay. After the clay had dried, it cracked badly and allowed the air to pass. The stopping was then plastered with wood-fiber cement as shown in Plate II, *A*, the result being decidedly satisfactory. At a total cost of \$1.60 per 80 square feet of stopping, the air leakage was reduced to 28 feet per stopping.

Table 13, showing labor costs for building gob stoppings of different sizes, follows:

TABLE 13.—*Cost of labor for building gob stoppings of different sizes.*

Area.	Depth.	Cost of labor.		
		Per stop- ping.	Per square foot.	Per 80 square feet.
<i>Square feet.</i>	<i>Feet.</i>			
55	8	\$7. 59	\$0. 138	\$11. 04
90	5½	10. 50	. 117	9. 36
132	9	14. 25	. 108	8. 64
84	9	8. 49	. 101	8. 08
60	-----	5. 29	. 088	7. 04
36	-----	2. 62	. 073	5. 82
143	6	9. 25	. 065	5. 18
52	6	3. 37	. 065	5. 18
147	6	7. 86	. 054	4. 32
187½	12	13. 10	. 070	5. 60
Average..	-----		. 088	7. 04

BOARD STOPPINGS.

Board stoppings are widely used in Illinois coal mines. They may be easily and cheaply built and are suitable for the crosscuts in short butt entries and for the break-throughs in rooms. On main entries where the ventilating pressure causes a high water gage, the cost of air leaks in board stoppings is large; and at places where the period of service is over 3 years, the maintenance charges and the renewal repairs are costly.

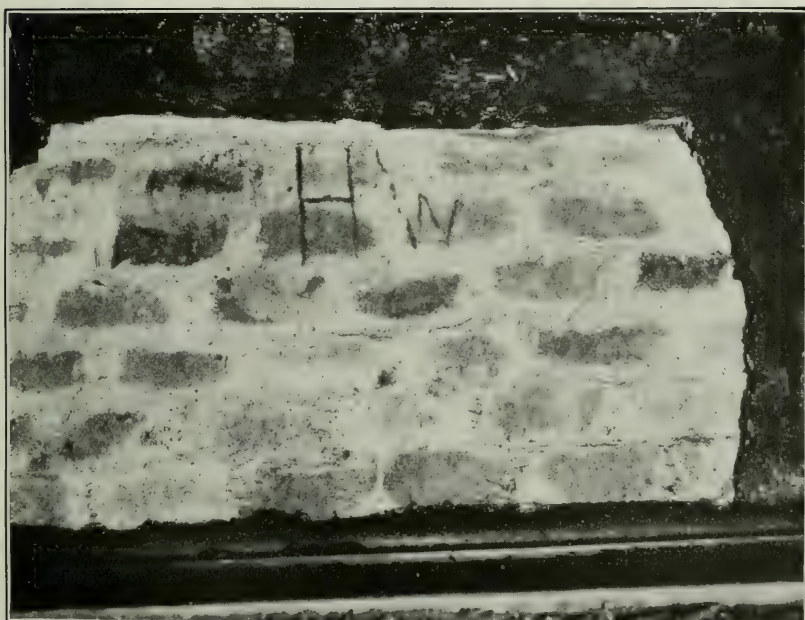
Tongue-and-groove boards are often substituted for rough lumber in order to obtain tight stoppings, and may be given additional life by painting. The importance of tight joints is evident. Tongue-and-groove lumber and wood-fiber plaster are materials that can be used to build tight stoppings; but in usual practice stoppings made of smooth boards are leaky. There are two reasons for leakage.

In the first place, plaster will not adhere firmly to smooth boards that are subjected to the vibration incident to mining operations. Even if the plaster would adhere, little could be gained in plastering the surface of the stopping. Tongue-and-groove boards will not leak, and paint is a far better preservative than plaster. Wood-fiber plaster, however, is necessary at the joints where the stopping touches the ribs, roof, and floor, and at those joints a roughened surface must be offered in order that the plaster will hold. Roughening may be accomplished by scratching the surface of the stopping with a sharp pick; or better still by nailing a strip of lath, prop bark, or rough wood within 1 inch of the four edges of the stopping.

In the second place, many board stoppings leak because the attempt has been made to build them without cutting a V-shaped groove into the rib to hold the cement.



A. GOB STOPPING FACED WITH DRY WALL OF SLATE AND ROOF COAL.



B. CONCRETE-BLOCK STOPPING.

Figure 1 shows a method for making a tongue-and-groove stopping efficient as long as the wood lasts.

Plate II, *B*, shows a rough-lumber stopping coated with wood-fiber cement. The loss of air through such a stopping was 112 cubic feet per minute, being considerably less than through an uncoated stopping.

Figure 2 shows a rough-board stopping that differs somewhat from the usual type. The boards are nailed to the props like clapboards on a house except that they are upside down. The upper edge of each board is beveled and offers a recess which holds mortar much more securely than when plastered on the face of an ordinary stopping.

A cheap and efficient stopping for room entries may be constructed by nailing Berkytt lath to props and covering the lath on the intake side with a $\frac{1}{2}$ -inch coat of wood fiber. The Berkytt lath are boards,

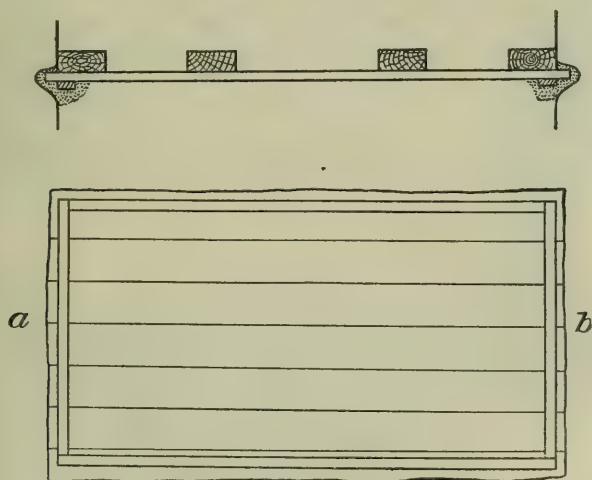


FIGURE 1.—Properly constructed stopping made of tongue-and-groove lumber. Note braces and grooves cut into ribs.

on one surface of which grooves are cut for the retention of the wood fiber.

The items that enter into the first cost of a stopping of this kind are reported as follows for a size $7\frac{1}{2}$ by 9 feet:

Material:

Wood fiber, 100 pounds.....	\$0.40
Byrkett lath, 70 square feet, at \$11.50 per 1,000.....	.81
Props, 3 at 8 cents.....	.24
Nails.....	.05
	\$1.50

Labor:

Setting props and nailing lath, 4 hours at $35\frac{1}{2}$ cents.....	1.42
Mixing wood fiber and plastering, 4 hours at $35\frac{1}{2}$ cents.....	1.42
	2.84

Total.....	4.34
------------	------------

In the figure for total cost, no allowance is made for cost of delivery of materials from the mine entrance to the crosscut in which the stopping is to be built, and no item is given for the cost of cutting the latches or grooves in the ribs. In order that the figure for total cost may be compared with those given in Table 2, the following additions should be made:

Total cost as above for area of $67\frac{1}{2}$ square feet.....	\$4. 34
Addition for larger stopping, 80-square-foot area.....	. 80
Addition for delivery of material.....	. 64
Addition for cutting groove in ribs.....	. 64

Total.....	6. 42
------------	-------

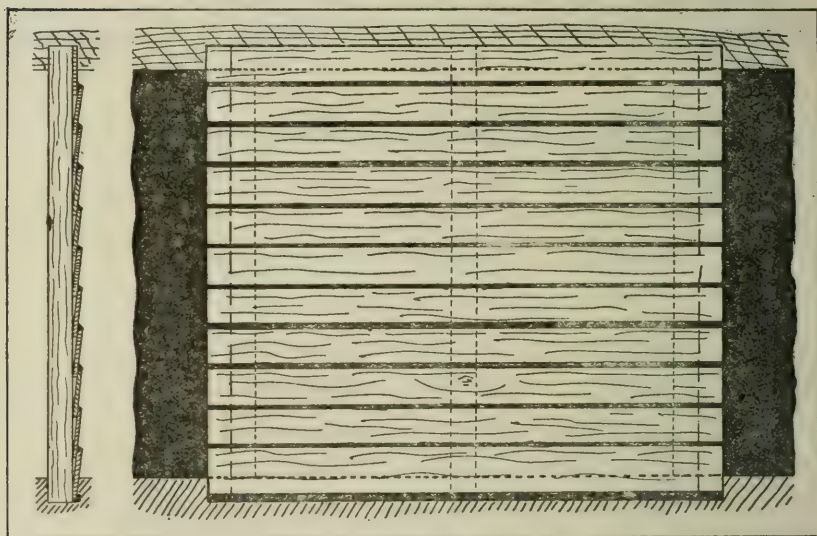
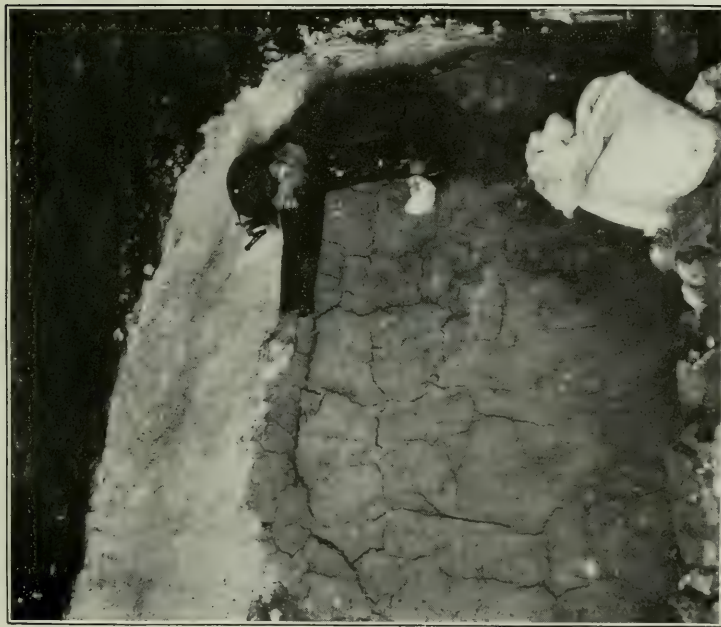


FIGURE 2.—Rough-board stopping, inverted clapboard type.

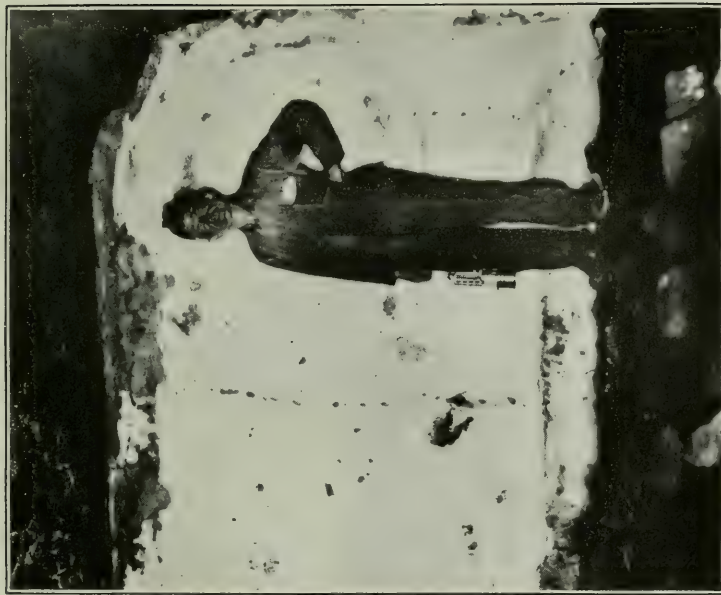
BRICK STOPPINGS.

In a few mines, bricks are used in building efficient stoppings. Operators report that except in locations where brickyards are close to the mines, it is cheaper to use concrete than brickwork for permanent stoppings.

At one mine where 8-inch brick stoppings were shaken down by the shooting, a remedy was suggested by George S. Rice, chief mining engineer of the Bureau of Mines. A double-arched stopping was built, each arch being 4 inches thick, and the two arches being opposed and touching at the center, as shown in figure 3. The space between the walls was filled with dirt and clay lightly tamped.



A. GOB STOPPING FACED WITH 12 INCHES OF CLAY. THE CRACKS IN THE CLAY ARE BEING PLASTERED WITH WOOD-FIBER CEMENT.



B. ROUGH-LUMBER STOPPING COATED WITH WOOD-FIBER CEMENT.

CONCRETE STOPPINGS.

In many mines, concrete is the most suitable material for use in the construction of efficient stoppings in the crosscuts between main air passageways. Concrete stoppings may be constructed at reasonable first cost, they have low maintenance charges, they are durable,

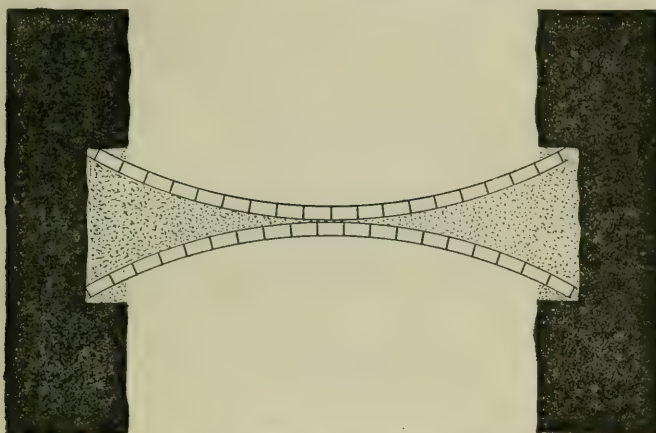


FIGURE 3.—Plan of arched brick stopping.

incombustible, and unaffected by water, and they have a high bearing strength to assist in supporting the roof.

The installation costs as reported by several operators are as follows:

TABLE 14.—*First costs of concrete-block stoppings.*

Size of blocks.			Cost of blocks.	Cost of cement mortar.	Cost of delivery into mine.	Cost of building stopping.	Total first cost.
Height.	Length.	Breadth.					
<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>					
8	20	5	\$3.96	\$0.31	\$0.71	\$5.24	\$10.22
12	24	8	8.36	.36	.71	7.25	16.68
10	20	6	2.16	.32	.71	5.46	8.65
8	18	6	6.57	.37	.71	2.84	10.49
8	16	8	4.10	.52	.71	2.62	7.95
8	16	8	3.28	.52	.71	2.84	7.35
Average cost.			4.74	.40	.71	4.38	10.29

At many mines, where care has been used in the construction of the joint at the roof and the ribs, there have been no maintenance charges. At one mine it was reported that this item amounted to 5 cents per annum per stopping, based on an expenditure of 50 cents per year for every 10 stoppings.

Renewal repairs are unnecessary in concrete stoppings because, under ordinary mining conditions, the life of a concrete stopping is longer than the period during which service is required.

There is available little information on the annual cost of emergency repairs for concrete stoppings. One operator reports that 10 per cent of such stoppings are each year affected by heavy shots and require repairs amounting to 50 cents each. Most operators find no occasion for emergency repairs. A nearby windy or blown-out shot, or a general mine explosion, is usually the only extraordinary agent that destroys such stoppings; and even then the wreckage from them is small and is easily cleaned up, and most of the blocks are suitable for reuse. When the bottom is soft and has a tendency to heave, it has been found advisable to lay the foundation course of cement blocks at a right angle to the other blocks in order that a larger bearing surface may be obtained.

The methods and appliances used in the manufacture of cement blocks at the mine are described by S. O. Andros in Bulletins 4 and 6 of the Illinois Coal-Mining Investigations.

Plate I, *B*, shows an efficient cement-block stopping.

LINE BRATTICES.

In a few mines in southern Illinois, where some of the entries are being driven into gaseous territory, line brattices are constructed in order to conduct the ventilating current from the last crosscut to the working face. In mine-rescue and mine-recovery work it is often necessary to use line brattices to expedite the movement of a body of afterdamp. Except for such work, line brattices are seldom used in Illinois coal mines.

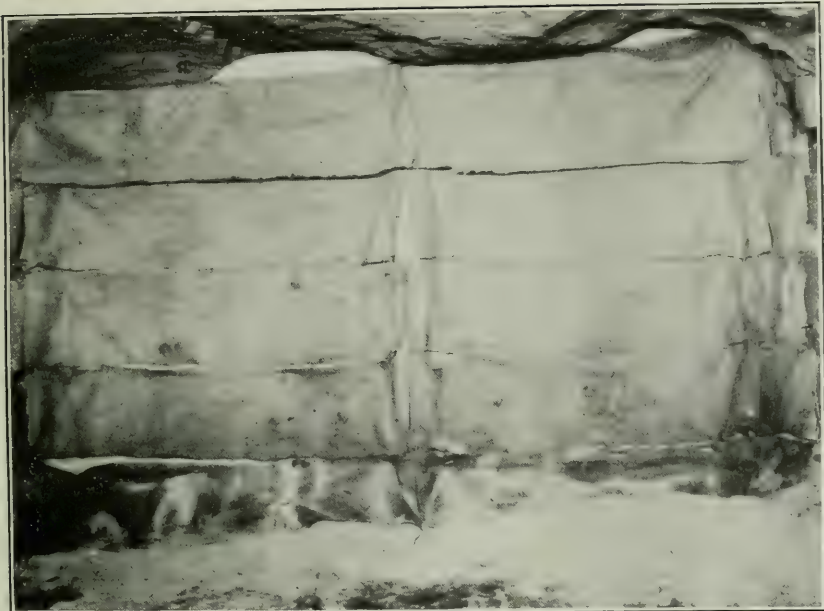
Plate III, *B*, shows the outer or crosscut end of a line of brattice in the Bureau of Mines experimental mine, at Pittsburgh, Pa., and Plate IV shows the inner or face end of the same brattice. When a line of brattice cloth is run from the last crosscut to the face of an entry that contains explosive or noxious gases, a miner should nail the canvas on the intake side to avoid danger from the gases.

ROCK-DUST-PROTECTED STOPPING.

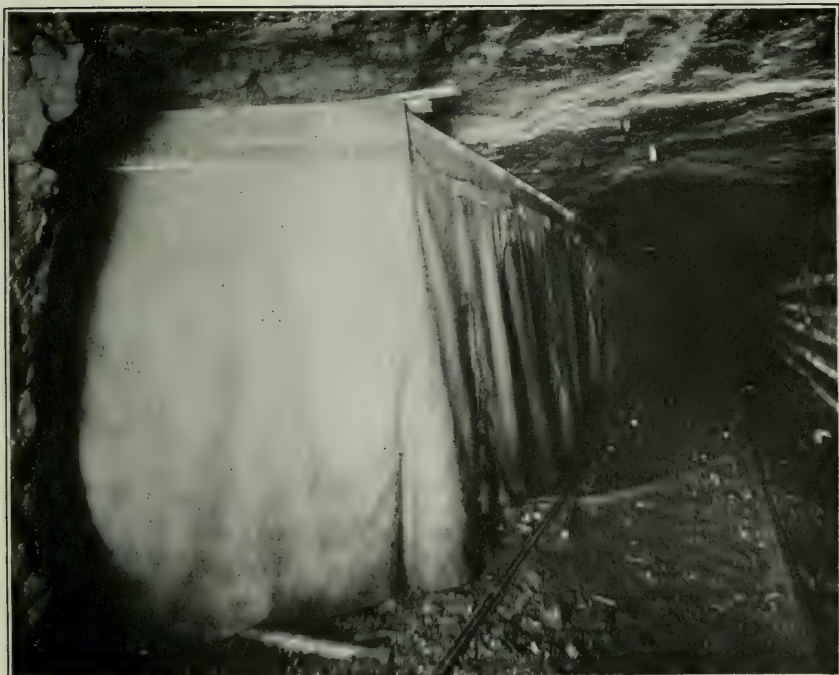
A rock-dust-protected stopping has been designed by George S. Rice, chief mining engineer of the Bureau of Mines, for checking explosions that may pass through a crosscut. In one explosion test at the bureau's experimental mine it prevented an explosion from entering the butt headings, and in other tests, when placed in crosscuts, it prevented the explosion in one butt from passing into the parallel butt entry. The construction of the stopping and method of erection are fully described in Technical Paper 84^a of the bureau.

The stopping is a double one, as shown in figure 4. The principle is that when pressure from a slight explosion is thrown on the stop-

^a Rice, G. S., and Jones, L. M., Methods of preventing and limiting explosions in coal mines: Technical Paper 84, Bureau of Mines, 1915, pp. 32-35.



A. ROCK-DUST-PROTECTED STOPPING.



B. OUTER OR CROSSCUT END OF LINE BRATTICE, BUREAU OF MINES EXPERIMENTAL MINE.



INNER OR FACE END OF A LINE BRATTICE.

ing, half of it goes out and the other half is left in position with some dust on the shelves to extinguish a delayed flame. In case of a very violent explosion, the whole stopping goes out at once and the rock dust extinguishes the flame. This type is adapted for use with any kind of a solid stopping as a core, or it may be used by itself.

The construction is simple and is not expensive at mines where fine inert dust is available; such as fine ashes, or the fine screenings from limestone quarries, which, in Illinois, can be purchased for \$1 to \$2 per ton. The curtains prevent the dust from becoming damp under ordinary mining conditions. In especially wet mines it may

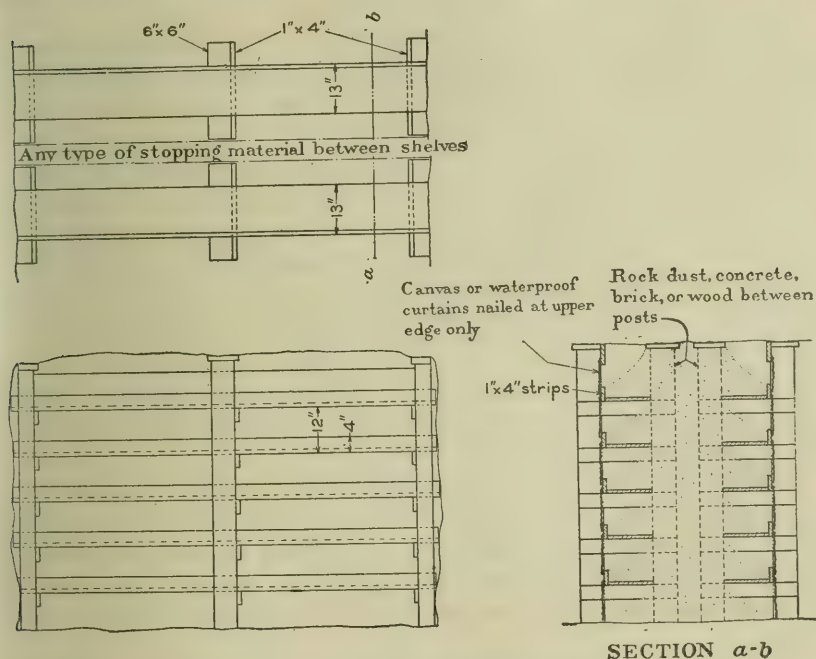


FIGURE 4.—Rock-dust-protected stopping designed by Bureau of Mines.

be necessary to put waterproofing over the stopping so that the water may be deflected to one side or the other. Galvanized-iron sheets may be used or the walls may be plastered with neat cement.

Plate III, A, shows the rock-dust-protected stopping as erected at the bureau's experimental mine.

COLLAPSIBLE STOPPING.

A great deal has been written about the use of collapsible stoppings which would go out at the instant of an explosion and thus relieve the pressure of the explosion wave. The writer believes that the arguments for and against the use of these stoppings are not

conclusive, and that the initiation of an explosion should be prevented by the use of permissible explosives, by efficient humidification, and by ample ventilation to prevent the accumulation of pockets of methane, rather than that recourse should be had to a flimsy stopping which will permit the leakage of air required for the well-being of the men at the face. If it is thought best to use a collapsible stopping the rock-dust stopping previously described accomplished the purpose sought and also furnished means of extinguishing that branch of the explosion that blew down the stopping.

CONCLUSIONS.

One of the most obvious conclusions from the inspection of several hundred stoppings is that the efficiency of a mine stopping to prevent the leakage of air depends more on the care with which the joints are made than on the material that is used in construction. Some concrete stoppings were found to leak large quantities of air because they were not set into the rib, and new tongue-and-groove stoppings were tight when carefully constructed. The amortised first cost is a small item when compared with the maintenance and efficiency charges, and the cost of cutting a latch in the rib is only a small part of the initial expense. The preparation of grooves in the ribs should therefore always precede the erection of stoppings.

A general protest is being made against high velocities in the ventilating currents in coal mines. The practical facts on which this protest is based are as follows:

1. The amount of power required to move a given volume of air increases directly as the cube of the velocity. If leaky stoppings make it necessary for the fan to deliver 4 times as much air as would be required if the stoppings were tight, the cost of the power to move the larger volume of air would be 64 times that for the smaller volume.

2. As the temperature and the relative humidity of the upcast at any mine are approximately constant throughout the year, the quantity of moisture extracted from the dust will vary directly with the quantity of air in circulation. If therefore the fan furnishes 4 times as much air as would be required if the stoppings were efficient, the amount of water extracted from the mines during cold weather would be increased nearly fourfold. The drying out of coal mines in the winter causes a dangerous condition to exist in the event of a blown-out or windy shot or the ignition of a pocket of gas.

3. The weight of fine dust that is in suspension in the mine air varies approximately as the cube of the velocity of the ventilating current. This relation has been established by W. H. Carrier, chief engineer of the Buffalo Forge Co., in experiments to determine the

weight of material which can be handled by velocities above the critical speed. The greater the velocity of the air, therefore, the larger will be the amount of fine coal dust that will be in suspension and deposited evenly along the entry way ready to assist in the propagation of an explosion throughout the mine.

It is evident that mine economy and mine safety require that stoppings along the main air passageways should be efficiently installed and maintained.

PUBLICATIONS ON MINE ACCIDENTS AND METHODS OF COAL MINING.

Limited editions of the following Bureau of Mines publications are temporarily available for free distribution. Requests for all publications can not be granted, and applicants should select only those publications that are of especial interest to them. All requests for publications should be addressed to the Director, Bureau of Mines, Washington, D. C.

BULLETIN 17. A primer on explosives for coal miners, by C. E. Munroe and Clarence Hall. 61 pp., 10 pls., 12 figs. Reprint of United States Geological Survey Bulletin 423.

BULLETIN 20. The explosibility of coal dust, by G. S. Rice, with chapters by J. C. W. Frazer, Axel Larsen, Frank Haas, and Carl Scholz. 204 pp., 14 pls., 28 figs.

BULLETIN 42. The sampling and examination of mine gases and natural gas, by G. A. Burrell and F. M. Seibert. 1913. 116 pp., 2 pls., 23 figs.

BULLETIN 45. Sand available for filling mine workings in the Northern Anthracite Coal Basin of Pennsylvania, by N. H. Darton. 1913. 33 pp., 8 pls., 5 figs.

BULLETIN 46. An investigation of explosion-proof mine motors, by H. H. Clark. 1912. 44 pp., 6 pls., 14 figs.

BULLETIN 48. The selection of explosives used in engineering and mining operations, by Clarence Hall and S. P. Howell. 1913. 50 pp., 3 pls., 7 figs.

BULLETIN 50. A laboratory study of the inflammability of coal dust, by J. C. W. Frazer, E. J. Hoffman, and L. A. Scholl, jr. 1913. 60 pp., 95 figs.

BULLETIN 52. Ignition of mine gases by the filaments of incandescent electric lamps, by H. H. Clark and L. C. Hsley. 1913. 31 pp., 6 pls., 2 figs.

BULLETIN 56. First series of coal-dust explosion tests in the experimental mine, by G. S. Rice, L. M. Jones, J. K. Clement, and W. L. Egy. 1913. 115 pp., 12 pls., 28 figs.

BULLETIN 60. Hydraulic mine filling; its use in the Pennsylvania anthracite fields; a preliminary report, by Charles Enzian. 1913. 77 pp., 3 pls., 12 figs.

BULLETIN 62. National mine-rescue and first-aid conference, Pittsburgh, Pa., September 23-26, 1912. By H. M. Wilson. 1913. 74 pp.

BULLETIN 68. Electric switches for use in gaseous mines, by H. H. Clark and R. W. Crocker. 1913. 40 pp., 6 pls.

BULLETIN 69. Coal-mine accidents in the United States and foreign countries, compiled by F. W. Horton. 1913. 102 pp., 3 pls., 40 figs.

BULLETIN 72. Occurrence of explosive gases in coal mines, by N. H. Darton. 1915. 248 pp., 7 pls., 33 figs.

BULLETIN 82. International conference of mine-experiment stations, Pittsburgh, Pa., U. S. A., September 14-21, 1912, compiled by G. S. Rice. 1914. 99 pp., 4 figs.

BULLETIN 83. The humidity of mine air, with especial reference to coal mines in Illinois, by R. Y. Williams. 1914. 69 pp., 2 pls., 7 figs.

BULLETIN 87. Houses for mining towns, by J. P. White. 1914. 64 pp., 8 pls., 9 figs.

TECHNICAL PAPER 4. The electrical section of the Bureau of Mines, its purpose and equipment, by H. H. Clark. 1911. 12 pp.

TECHNICAL PAPER 6. The rate of burning of fuse as influenced by temperature and pressure, by W. O. Snelling and W. C. Cope. 1912. 28 pp.

TECHNICAL PAPER 7. Investigations of fuse and miners' squibs, by Clarence Hall and S. P. Howell. 1912. 19 pp.

TECHNICAL PAPER 11. The use of mice and birds for detecting carbon monoxide after mine fires and explosions, by G. A. Burrell. 1912. 15 pp.

TECHNICAL PAPER 13. Gas analysis as an aid in fighting mine fires, by G. A. Burrell and F. M. Seibert. 1912. 16 pp., 1 fig.

TECHNICAL PAPER 14. Apparatus for gas-analysis laboratories at coal mines, by G. A. Burrell and F. M. Seibert. 1913. 24 pp., 7 figs.

TECHNICAL PAPER 15. An electrolytic method of preventing corrosion of iron and steel, by J. K. Clement and L. V. Walker. 1913. 19 pp., 10 figs.

TECHNICAL PAPER 17. The effect of stemming on the efficiency of explosives, by W. O. Snelling and Clarence Hall. 1912. 20 pp., 11 figs.

TECHNICAL PAPER 18. Magazines and thaw houses for explosives, by Clarence Hall and S. P. Howell. 1912. 34 pp., 1 pl., 5 figs.

TECHNICAL PAPER 19. The factor of safety in mine electrical installations, by H. H. Clark. 1912. 14 pp.

TECHNICAL PAPER 21. The prevention of mine explosions, report and recommendations, by Victor Watteyne, Carl Meissner, and Arthur Desborough. 12 pp. Reprint of United States Geological Survey Bulletin 369.

TECHNICAL PAPER 22. Electrical symbols for mine maps, by H. H. Clark. 1912. 11 pp., 8 figs.

TECHNICAL PAPER 28. Ignition of mine gas by standard incandescent lamps, by H. H. Clark. 1912. 6 pp.

TECHNICAL PAPER 29. Training with mine-rescue breathing apparatus, by J. W. Paul. 1912. 16 pp.

TECHNICAL PAPER 39. The inflammable gases in mine air, by G. A. Burrell and F. M. Seibert. 1913. 24 pp., 2 figs.

TECHNICAL PAPER 43. The effect of inert gases on inflammable gaseous mixtures, by J. K. Clement. 1913. 24 pp., 1 pl., 8 figs.

TECHNICAL PAPER 44. Safety electric switches for mines, by H. H. Clark. 1913. 8 pp.

TECHNICAL PAPER 47. Portable electric mine lamps, by H. H. Clark. 1913. 13 pp.

TECHNICAL PAPER 48. Coal-mine accidents in the United States, 1896-1912, with monthly statistics for 1912, compiled by F. W. Horton. 1913. 74 pp., 10 figs.

TECHNICAL PAPER 52. Permissible explosives tested prior to March 1, 1913, by Clarence Hall. 1913. 11 pp.

TECHNICAL PAPER 58. The action of acid mine water on the insulation of electric conductors; a preliminary report, by H. H. Clark and L. C. Ilsley. 1913. 26 pp., 1 fig.

TECHNICAL PAPER 69. Production of explosives in the United States during the calendar year 1912, compiled by A. H. Fay. 1914. 8 pp.

TECHNICAL PAPER 71. Permissible explosives tested prior to January 1, 1914, by Clarence Hall. 1914. 12 pp.

TECHNICAL PAPER 75. Permissible electric lamps for miners, by H. H. Clark, 1914. 21 pp., 3 figs.

TECHNICAL PAPER 76. Notes on the sampling and analysis of coal, by A. C. Fieldner. 1914. 59 pp., 6 figs.

TECHNICAL PAPER 77. Report of the Committee on Resuscitation from Mine Gases, by W. B. Cannon, George W. Crile, Joseph Erlanger, Yandell Henderson, and S. T. Meltzer. 1914. 36 pp., 4 figs.

TECHNICAL PAPER 78. Specific-gravity separation applied to the analysis of mining explosives, by C. G. Storm and A. L. Hyde. 1914. 13 pp.

TECHNICAL PAPER 84. Methods of preventing and limiting explosions in coal mines, by G. S. Rice and L. M. Jones. 1915. 50 pp., 14 pls. 5 figs.

TECHNICAL PAPER 100. Permissible explosives tested prior to March 1, 1915, by S. P. Howell. 1915. 16 pp.

TECHNICAL PAPER 101. Permissible explosion-proof electric motors for mines; conditions and requirements for test and approval, by H. H. Clark. 1915. 17 pp., 2 pls., 1 fig.

TECHNICAL PAPER 112. The explosibility of acetylene, by G. A. Burrell and G. G. Oberfell. 1915. 15 pp.

TECHNICAL PAPER 119. The limits of inflammability of mixtures of methane and air, by G. A. Burrell and G. G. Oberfell. 1915. 30 pp., 4 figs.

MINERS' CIRCULAR 5. Electrical accidents in mines, their causes and prevention, by H. H. Clark, W. D. Roberts, L. C. Ilsley, and H. F. Randolph. 1911. 10 pp., 3 pls.

MINERS' CIRCULAR 7. Use and misuse of explosives in coal mining, by J. J. Rutledge. 1914. 51 pp., 8 figs.

MINERS' CIRCULAR 8. First-aid instructions for miners, by M. W. Glasgow, W. A. Raudenbush, and C. O. Roberts. 1913. 67 pp., 51 figs.

MINERS' CIRCULAR 11. Accidents from mine cars and locomotives, by L. M. Jones. 1912. 16 pp.

MINERS' CIRCULAR 12. Use and care of miners' safety lamps, by J. W. Paul. 1913. 16 pp., 4 figs.

MINERS' CIRCULAR 13. Safety in tunneling, by D. W. Brunton and J. A. Davis. 1913. 19 pp.

MINERS' CIRCULAR 14. Gases found in coal mines, by G. A. Burrell and F. M. Seibert. 1914. 23 pp.

MINERS' CIRCULAR 15. Rules for mine-rescue and first-aid field contests, by J. W. Paul. 1913. 12 pp.

MINERS' CIRCULAR 16. Hints on coal-mine ventilation, by J. J. Rutledge. 1914. 22 pp.

MINERS' CIRCULAR 21. What a miner can do to prevent explosions of gas and coal dust, by G. S. Rice. 1915. 24 pp.

INDEX.

A.		F.	
	Page.		Page.
Air current, high velocity of, objections to...	24, 25	Fan, ventilating, horsepower required by...	14, 15
Air leakage through stoppings, loss by.....	13-16	Formula for.....	13
Data on.....	15, 16	Definition of.....	6
Determination of.....	6, 13	See also various types of mine stoppings.	
Effect of.....	14	Franklin County, Ill., mines in, efficiency of	
Factors determining.....	13	stoppings at.....	14
Andros, S. O., acknowledgments to.....	5		
On concrete-block stoppings.....	22	G.	
B.		Gob stoppings, air leaks in, loss by.....	16
Board stoppings, air leaks in, causes of.....	18	Description of.....	17
Loss by.....	16	Emergency repairs for, cost of.....	12, 13, 16
Description of.....	18	First cost of.....	9, 13, 16, 18
Emergency repairs for, cost of.....	12, 13, 16	Amortization of.....	10
Figure showing.....	19, 20	Maintenance charges for.....	11, 13, 16
First cost of.....	9, 13, 16, 19, 20	Objection to.....	17
Amortization of.....	10	Renewal repairs for, cost of.....	11, 13, 16
Maintenance charges for.....	11, 13, 16	Types of.....	9
Renewal repairs for, cost of.....	11, 13, 16	View of.....	18
Types of.....	9	I.	
Brattice, definition of.....	6	Illinois mines, output of.....	7
Line, construction of.....	22	Stoppings in, size of.....	7
Views of.....	22	Illinois State Geological Survey, cooperation	
Brick stopping, plan of.....	21	of.....	5
Brick stoppings, air leaks in, loss by.....	16	M.	
Description of.....	20	Macoupin County, Ill., mines in, efficiency of	
Emergency repairs for, cost of.....	12, 13, 16	stoppings at.....	14
First cost of.....	9, 13, 16	Maintenance charges, cost of.....	10, 11
Amortization of.....	10	Definition of.....	6
Maintenance charges for.....	11, 13, 16	See also various types of mine stoppings.	
Renewal repairs for, cost of.....	11, 13, 16	Mine, size of, relation of, to number of stop-	
Types of.....	9	pings.....	8
Bureau of Mines, cooperation of.....	5	R.	
C.		Renewal repairs, cost of.....	11
Carrier, W. H., on relation between dust in		Definition of.....	6
air and ventilating current.....	25	See also various types of stoppings.	
Christian County, Ill., mine in, efficiency of		Repairs. See Emergency repairs; Renewal	
stoppings at.....	14	repairs.	
Collapsible stopping, possible advantage of..	24	Rice, G. S., acknowledgments to.....	5.
Concrete stoppings, advantages of.....	21	On construction of brick stoppings.....	20
Air leaks in, loss by.....	16	Rock-dust-protected stopping designed	
Description of.....	21, 22	by.....	22, 23
Emergency repairs for, cost of.....	12, 13, 16, 22	Rock-dust-protected stopping, advantages of.	23
First cost of.....	9, 13, 16, 21	Description of.....	22, 23
Amortization of.....	10	Figure showing.....	23
Maintenance charges for.....	11, 13, 16, 21	Operation of.....	22, 23
Renewal repairs for, cost of.....	11, 13, 16, 21	Ryan, J. T., acknowledgments to.....	5
Types of.....	9	S.	
Cost data, method of presenting.....	5, 6	St. Clair County, Ill., mines in, efficiency of	
See also First cost.		stoppings at.....	14
E.		Sangamon County, Ill., mine in, efficiency of	
Emergency repairs, cost of.....	12	stoppings at.....	14
Definition of.....	6		
See also various types of stoppings.			

	Page.		Page.
Slate stoppings, air leaks in, cost of.....	16	Stoppings, mine, data on, value of—Contd.	
Emergency repairs for, cost of.....	12, 13, 16	Purpose of	13
First cost of.....	9, 13, 16	Sizes of, variations in.....	7
Amortization of.....	10	Types of.....	6
Maintenance charges for.....	11, 13, 16	<i>See also</i> various types of stoppings.	
Renewal repairs for, cost of.....	11, 13, 16	U.	
Types of.....	9	University of Illinois, cooperation of.....	5
<i>See also</i> Gob stoppings.		V.	
Stoppings, mine, data on, value of.....	5	“Ventilation efficiency,” definition of.....	15
Definition of.....	6	W.	
Efficiency of, conditions determining....	24	Williamson County, Ill., mines in, efficiency	
Horsepower required for.....	15	of stoppings at.....	14
First cost of, amortization of.....	10		
Determination of.....	8, 9		
Investigation of, purpose of.....	7		
Number of, relation of, to size of mine...	8		



